University of Technology, Sydney

Faculty of Engineering and Information Technology

Research of Two Speed DCT Electric Power-train and Control System

A thesis submitted for the degree of

Doctor of Philosophy

Bo Zhu

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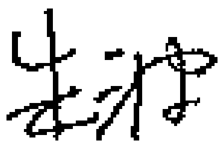
CERTIFICATE OF ORIGINALITY

I certify that the work in this thesis has not previously been submitted for a degree nor has it been submitted as part of the requirements for a degree except as fully acknowledged within the text.

I also certify that the thesis has been written by me. Any help that I have received in my research work and the preparation of the thesis itself has been acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

Bo Zhu



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GLOSSARY OF TERMS AND NOTATION

ABBREVIATIONS USED IN THIS THESIS

PEV -- Pure Electric Vehicle

HEV -- Hybrid Electric Vehicle

ICE -- Internal Combustion Engine

MT-- Manual Transmission

AT --Automatic Transmission

CVT --Continuously Variable Transmission

DCT-- Dual Clutch Transmission

AMT --Automated Manual Transmission

EVT --Electrically Variable Transmission

PDK -- Porsche Doppelkupplungsgetriebe (English: dual-clutch gearbox)

NEDC -- New European Driving Cycle

UDDS -- Urban Dynamometer Driving Schedule

ECE -- Economic Commission for Europe

EUDC-- Extra Urban Driving Cycle

FTP-72 -- Federal Test Procedure 72

FF -- Front mount Front drive

SOC – State of Charge

VCU --Vehicle Control Unit

MCU – Motor Control Unit

TCU—Transmission Control Unit

NOTATION

Chapter three

T_M -- Drive torque of motor;

i_g -- Gear ratio of transmission;

i_0 -- Gear ratio of final drive;

η_T -- Efficiency of the whole driveline from the motor to the driven wheel;

r --Radius of the driven wheels;

G --Weight of vehicle;

f --Rolling resistance coefficient;

α -- Road angle;

C_D -- Aerodynamic drag coefficient;

A --Vehicle front area;

δ -- Rotational inertia factor;

$V'\downarrow$ --Speed of downshift point;

$V\uparrow$ --Speed of up-shift point;

A_n -- the offset coefficient,

Chapter Four

u -- Vehicle speed;

δ -- Vehicle gyrating mass conversion factor;

m-- Vehicle mass;

i_g -- Gear ratio;

i_0-- Final ratio;

η_t -- Transmission efficiency;

r_d -- Wheel rolling radius;

T_c -- Clutch friction torque;

L -Sliding friction loss power;

ω – Speed;

m – Motor;

c 1 –Clutch 1;

c 2-- Clutch 2;

t1 –Clutch 1 engage or disengage time;

t2 –Clutch 2 engage or disengage time;

θ—Rotational displacement;

I – Inertia element;

C – Damping coefficient;

K –Stiffness coefficient;

T— Torque;

n -- Number of friction plates;

X – piston displacement;

X0 – Minimum displacement required for contact between friction plates;

μ_D— dynamic friction;

μ_S –Static friction;

r_O –Outside diameters of the clutch plates;

r_I – Inside diameters of the clutch plates;

F_A— Pressure load on the clutch;

T_{avg}— Average torque;

J— Conversion to the moment of inertia at the wheel （$kg \cdot m^2$）；

ω—Flywheel angular velocity（rad/s）；

M—Vehicle Mass（kg）；

v—Vehicle Speed（km/h）；

$r_{flywheel}$—Flywheel radius（m）；

SOC_0—Initial SOC value;

CAP_{MAX} -- Battery capacity;

V_{out} --Battery output voltage;

V-- Real voltage value;

I-- Real current value;

ABSTRACT

The research for this thesis is based on an international cooperation project with BAIC Motor Electric Vehicle Co.Ltd, UTS and AVL/NTC. It aims to develop a sample of a two speed DCT used in an electric drive system.

For the dual clutch's structural characteristics, one clutch is connected with one gear, so it is very simple to realize two speed driving. Simulation models are built in a co-simulation platform using AMESim and Simulink. Gear ratio selection is processed during the matching of Q60FB and C70GB vehicles. The ratios selected are 2nd and 3rd gear, and the ratios are 8.45 and 5.36. The prototype is modified from a VW 6spd DCT to operate at 2 speeds. The work primarily involves modification of the mechanical part of the gears and shaft, and changing the hydraulic parts.

To optimize vehicle dynamics and economic performance, a shifting schedule calculation method for PEVs is provided. This uses a graphical development method and is adapted for the purposes of simulations and experimental work. As long as gear shifts are initiated according to the schedule, the EM will be maintained at a higher efficiency operating region. As a result, the proposed method provides more efficient operations of the PEV.

Study of the control algorithm, including the vehicle control algorithm and shift control algorithm, is the core of this thesis. To investigate shift control and its calibration of a two speed DCT electric drive power-train, this thesis analyzes the shifting process. The vehicle control algorithm section follows the judgment of the pure electric multi-mode algorithm. The shift control section analyses the traditional DCT control shifting algorithm. In addition, the shifting control algorithm is

based on motor active braking control. Detailed shifting control algorithms are developed which include power-on and power-off methods. Corresponding simulation analysis has also been carried out.

The rig test uses the UTS power-train test bench for the purposes of modification. Calibration and testing works are employed for processing and the test rig mainly calibrates the shift control algorithm, DCT temperature testing, and NEDC and UDDS drive cycles testing.

Vehicle integration and testing are finished at BJEV. This is based on the BAIC independent brand car of Q60FB, with two gear DCT prototype mounting and road test calibration. Finally, the project tests dynamic and economic performance.